Optimizing U.S. Transportation Wedges: What We Learn from a Bottom-up Model

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Presentation to

International Energy Workshop

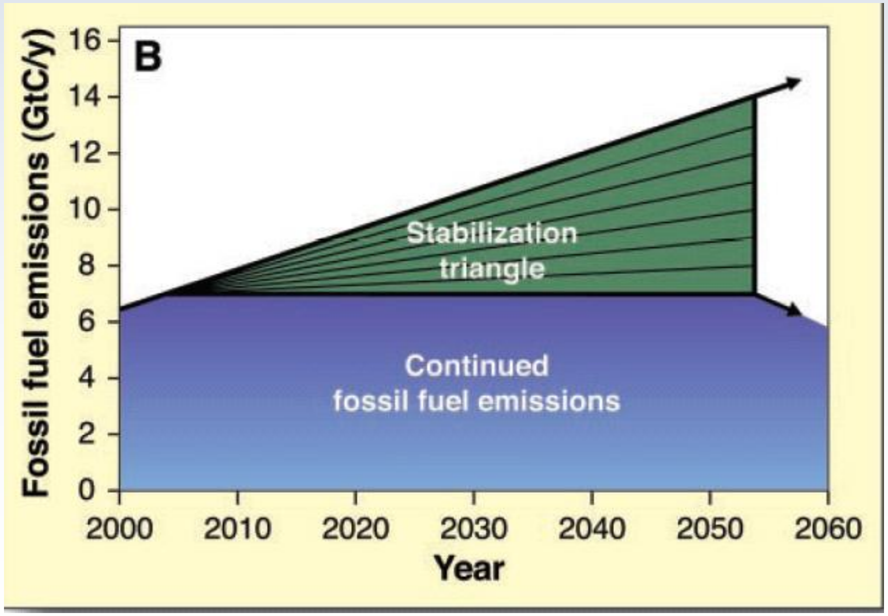
July 1, 2008

International Energy Agency, Paris

Solving Stabilization Wedges

Solving the Climate Problem for the Next 50 Years with Current Technologies (Pacala and Socolow, 2004)

- ‘Solving climate change this half-century implies keeping emissions at about current levels’.
- A portfolio of technologies exists today to do so.



Pacala, S., and R. Socolow. 2004.

- Efficient vehicles
- Reduced use of vehicles
- Capture CO_2 at H_2 plant
- Capture CO_2 at coal-to-synfuels Plant
- Wind H_2 in fuel-cell car for gasoline in hybrid car
- Biomass fuel for fossil fuel
- Reduced deforestation, plus reforestation, afforestation, and new plantations
- Conservation tillage

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Solving U.S. Transportation Wedges

- **Energy intensity reduction**
  - Increasing the efficiency of transportation technologies through improvement in vehicle technology or by adopting smaller, more efficient vehicles.
- **Fuel switching**
  - Increasing the share of vehicles using low-GHG fuels such as compressed natural gas, low-GHG ethanol, hydrogen, or electricity.
- **Lowering the global warming intensity (GWI) (on a life-cycle basis) of transportation fuels**
  1) making the fuel production process more efficient or reducing upstream emissions;
  2) blending lower-GWI fuel, such as ethanol or bio-diesel, into the fuel mix (e.g., E10 or B20); or
  3) producing fuel from low-GWI feedstock, such as ethanol from cellulosic materials instead of corn, or hydrogen from renewable energy sources such as biomass gasification or electrolysis using wind or solar power.
- **Demand reduction or travel mode change**.
  1) reducing the reliance on personal vehicles, increasing use of more efficient modes of transportation such as mass transit and rail,
  2) better land use policies that reduce transportation demand (such as smart growth policies that encourage high-density housing and mixed-use residential, retail, and business communities) and
  3) improve system efficiency (as by reducing congestion).

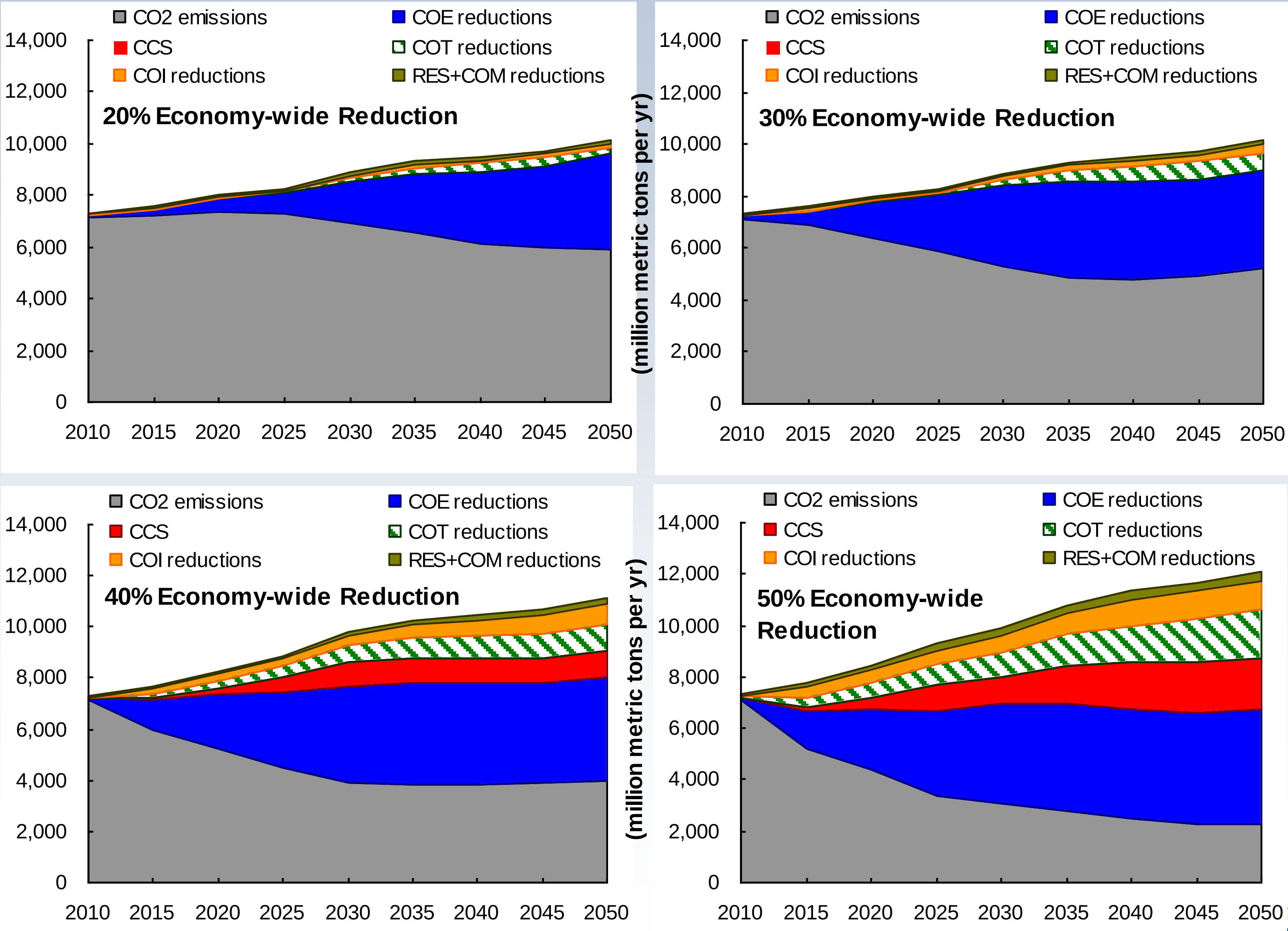
Exploring the Wedge Concept within Optimization Framework

- How we get there, and how cost affects adoption?
- The nature of the transition: smooth, abrupt, or transitional?
- The interactions between wedges: substitutes or complements?
- Robustness of the wedges to various uncertainties such as policy uncertainties, the levels of caps, or the modeling time horizon?

Scenarios Examined in the Wedge Paper

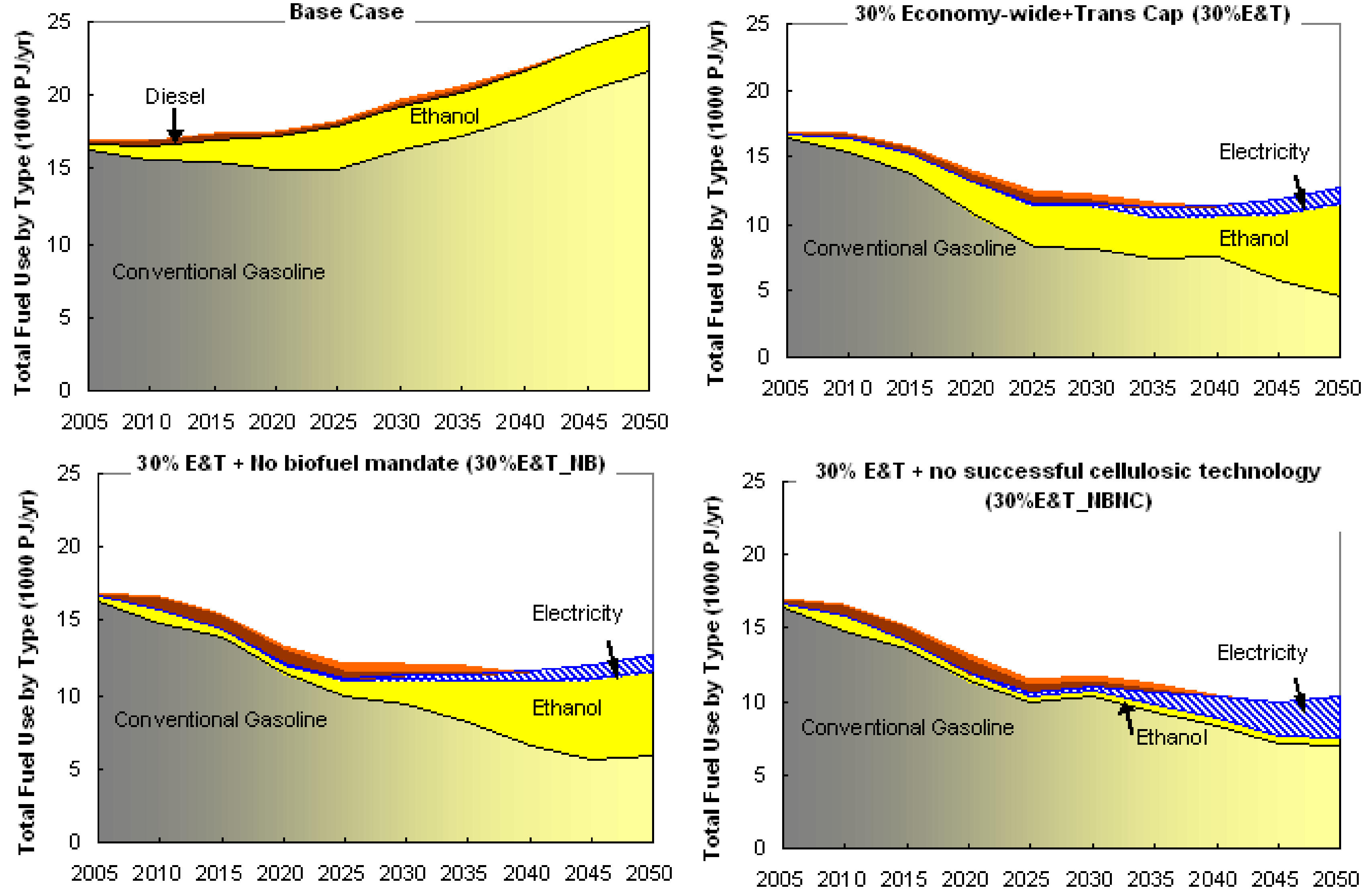
Scenario Name	Description	Note
Reference case (BAU)	Projections of the base case	Travel demand elasticity = -0.1, Vehicle technology discount rate = 0.33
10%E, 20%E, 30%E, 40%E, 50%E	10-50% Economy-wide cap	Elasticity = -0.3, Vehicle technology discount rate = 0.15
10%E&T, 20%E&T, 30%E&T	10-30% Economy-wide + transportation cap	
30%T	30% transportation only cap	
30%E&T_NCL	30% Economy-wide + transportation cap *without* shift in vehicle class	
30%E&T_NB	30% Economy-wide + transportation cap *without* biofuel mandate after 2015	
30%E&T_NBNC	30% Economy-wide + transportation cap *without* biofuel mandate after 2015 and no successful cellulosic ethanol technology	

How Would an Economy-Wide Cap-and-Trade Program Affect Transportation Reductions?



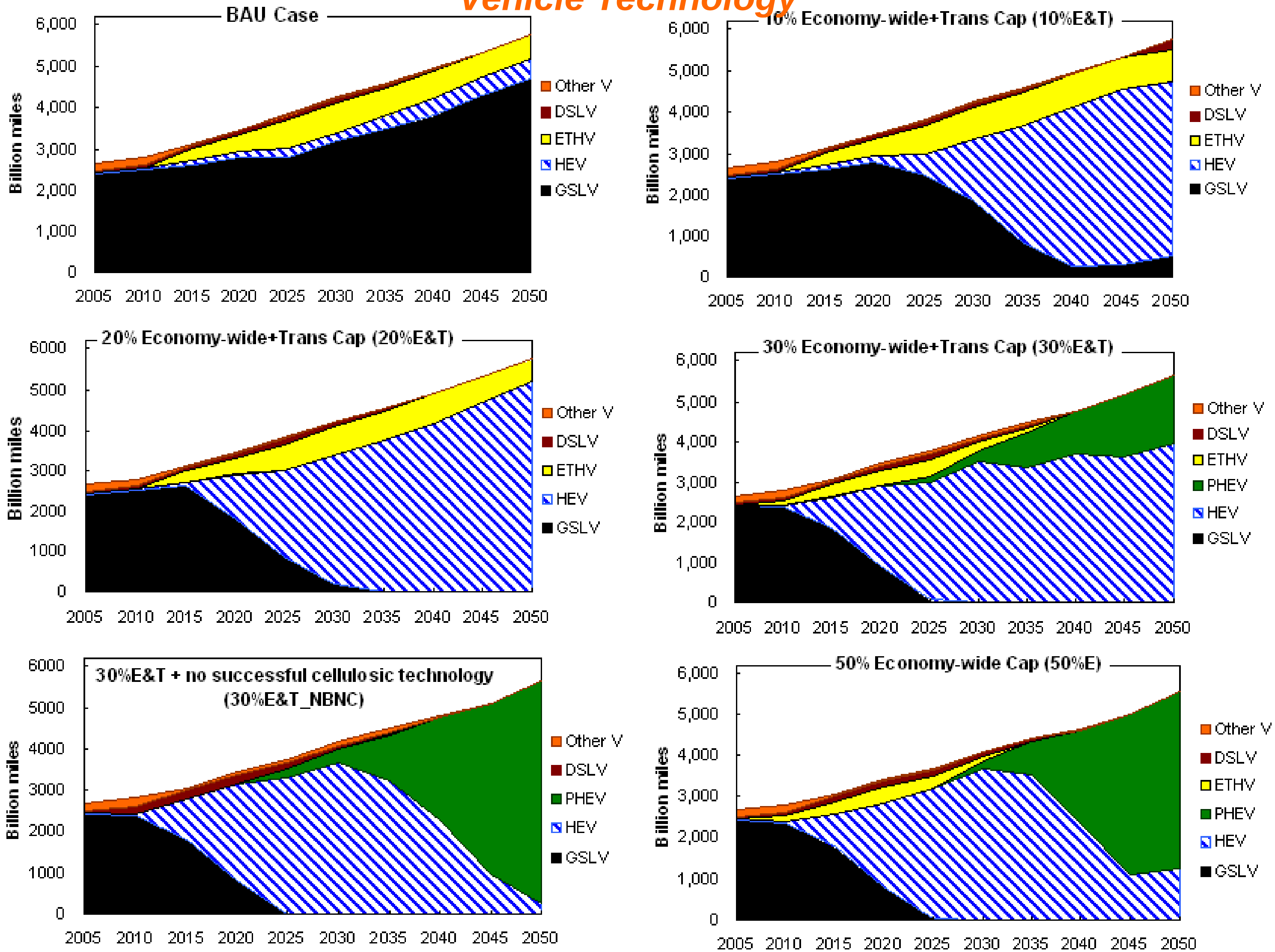
Optimized U.S. Transportation Wedges at 30% Reduction Level under Different Scenarios

Fuel Use

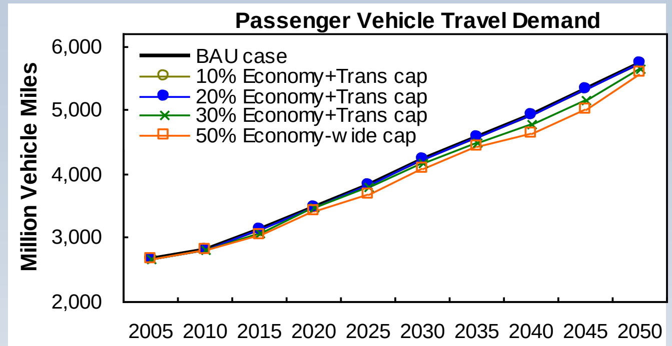


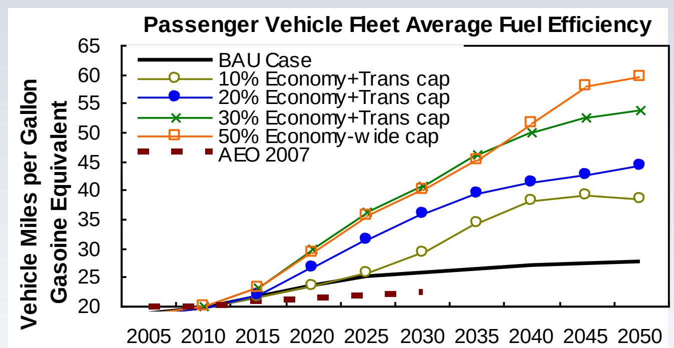
Scenario Analysis: Optimizing U.S. Transportation Wedges

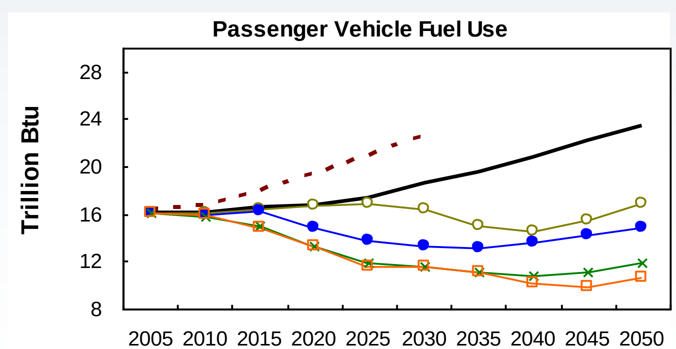
Vehicle Technology



Passenger Vehicle Travel Demand, Fuel Efficiency, and Total Fuel Use

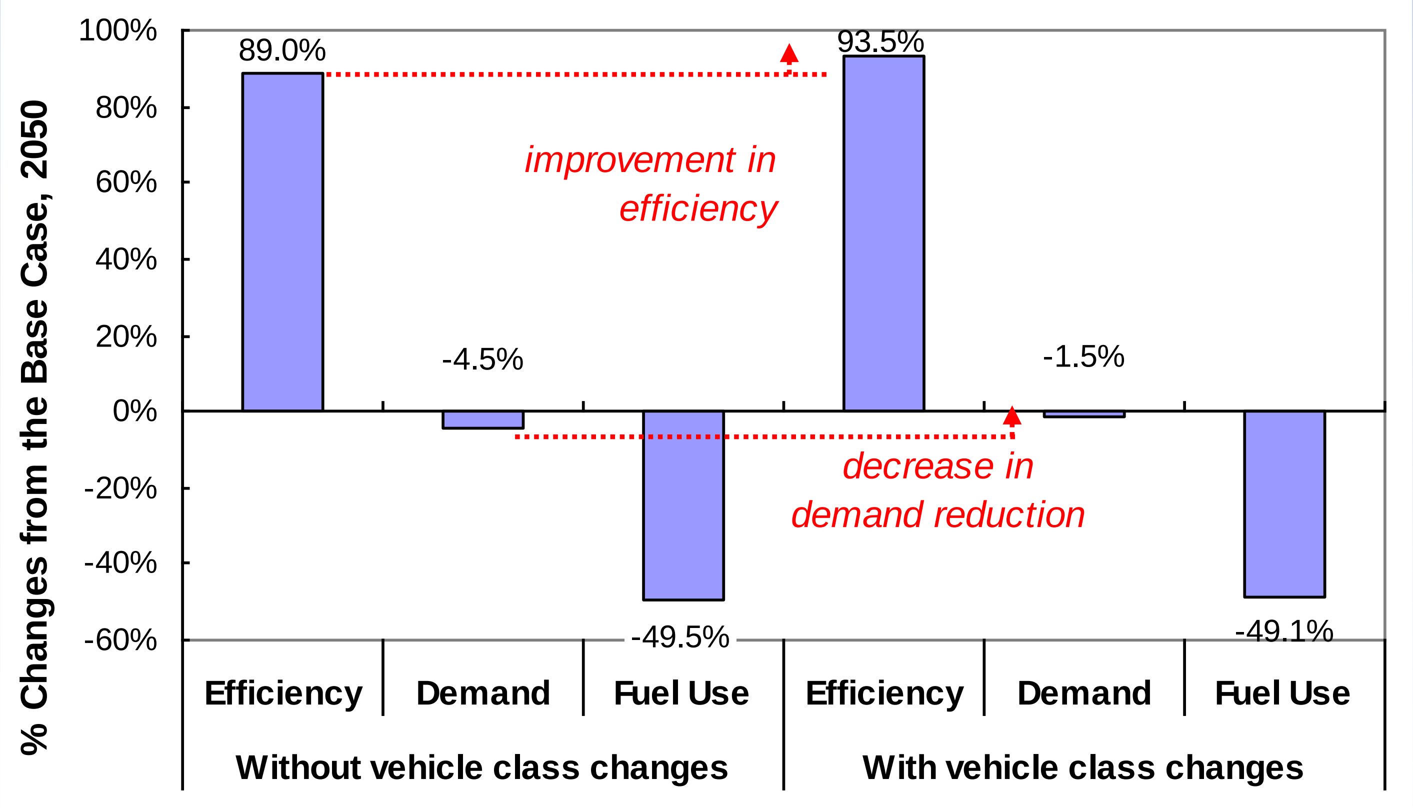






How Consumer Behavior May Affect Carbon Mitigation Options

- When consumers are able to respond to policies by switching to smaller, more efficient cars, their travel reductions in response to a stringent carbon cap are smaller
- A 2.39% improvement in efficiency in fact results in 0.74% increase in fuel use due to 3.14% increase in travel demand.



Exploring the Wedge Concept within Optimization Framework

- How we get there, and how cost affects adoption?
  - Without a separate cap, transportation sector is not likely to contribute to significant reductions
  - The least-cost stabilization wedges for the transportation sector include fuel use reduction and the adoption of low-GHG fuels, the adoption of advanced vehicle technologies, and increased vehicle efficiency
- The nature of the transition: smooth, abrupt, or transitional?
- The interactions between these wedges: substitutes or complements?
- Robustness of the wedges to various uncertainties such as policy uncertainties, the levels of caps, or the modeling time horizon?

Exploring the Wedge Concept within Optimization Framework

- How we get there, and how cost affects adoption?
- The nature of the transition: smooth, abrupt, or transitional?
  - Depending on the dynamics of supply and demand, price equilibrium, and constraints such as the details of the policies, the least-cost adoption pathway can be
    - smooth,
    - high-growth: some of the advanced hybrid and plug-in hybrid wedges
    - Transitional: some of the ethanol flex-fuel vehicles under most stringent scenarios are appropriate for short- to medium-term solutions, but need to be replaced by more advanced vehicle technologies in the long term
- The interactions between these wedges: substitutes or complements?
- Robustness of the wedges to various uncertainties such as policy uncertainties, the levels of caps, or the modeling time horizon?

Exploring the Wedge Concept within Optimization Framework

- How we get there, and how cost affects adoption?
- The nature of the transition: smooth, abrupt, or transitional?
- The interactions between these wedges: substitutes or complements?
  - Substitutes: the more the electricity system becomes decarbonized, the less the available savings from greater efficiency of electricity use, and vice versa.
  - Substitutes: the effect of demand reductions (both fuel use demand and travel demand) becomes smaller as a vehicle fleet becomes more efficient, and vice versa.
  - Complementary: the wedges for plug-in hybrid vehicles and electric vehicles expand as the electricity powering these vehicles is decarbonized
- Robustness of the wedges to various uncertainties such as policy uncertainties, the levels of caps, or the modeling time horizon?

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Exploring the Wedge Concept within Optimization Framework

- How we get there, and how cost affects adoption?
- The nature of the transition: smooth, abrupt, or transitional?
- The interactions between these wedges: substitutes or complements?
- Robustness of the wedges to various uncertainties such as policy uncertainties, the levels of caps, or the modeling time horizon?
  - some mitigation wedges play important roles in all scenarios: adoptions of HEVs and increases in vehicle efficiency (these two wedges are not mutually exclusive)
  - other wedges are sensitive to the **level of CO2 mitigation policies** (e.g., the PHEV wedge), **the details of certain policies** (e.g., the ethanol wedge), **consumer preferences** (the demand reduction wedge), **technology costs** (the hydrogen wedge), and **modeling period** (hydrogen)
  - maintaining a portfolio of viable technologies is essential to the success of policies aiming to achieve significant CO2 emission caps
  - More work is required to guide policies that aim to achieve the highest degree of successful outcome in the face of uncertainties

Policies in Reducing Transportation CO_2 Emissions

- U.S.
  - Mandates and subsidies (eg, US ethanol subsidies)
  - Renewable Fuel Standards (Energy Independence and Security Act 2007)
    - US RFS mandates 36 billion gallons/yr by 2022 (with 4 categories)
- California
  - Carbon tax, and cap and trade: Global Warming Solution Act, AB32
  - Vehicle programs
    - California Low Emission Vehicle Program (LEVP):
      - emissions-based policy, setting sales mandates for 6 categories of low-emission vehicles: low-emission vehicles (LEVs), ultra-low-emission vehicles (ULEVs), super-ultra low emission vehicles (SULEVs), partial zero-emission vehicles (PZEVs), advanced technology partial zero emission vehicles (AT-PZEVs), and zero-emission vehicles (ZEVs).
    - Vehicle GHG Emissions Standards AB 1493 (Pavley)
  - Fuels program
    - State Alternative Fuel Plan, AB 1007
    - **Low Carbon Fuel Standard: reducing the carbon intensity of transportation fuels by 10% by 2020**

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Acknowledgement

- Yeh, Sonia, A. E. Farrell, Richard Plevin, Alan Sanstad, and John Weyant. 2008. Optimizing U.S. Transportation Wedges: What We Learn from a Bottom-up Model Environmental Science & Technology: submitted.
- Daniel Sperling, Joan Ogden and Mark Delucchi